NEW MASTCAM MULTISPECTRAL ROCK CLASSES IN SULFATE-BEARING STRATA, GALE CRATER, MARS.

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Introduction: Orbital data of Gale Crater, Mars has identified a transition in the stratigraphy of Mt. Sharp indicating an environmental change from a wetter one that accommodated clay mineral formation to a drier environment that led to the precipitation of sulfates [1]. Mt. Sharp is not the only location on Mars for which this transition has been observed which suggests a global environmental change around the Noachian-Hesperian transition [1]. Also visible from orbit is a dark-toned marker band that lies within the sulfate-bearing strata hypothesized to be a volcanic ash deposit [2]. The Mars Science Laboratory (MSL) Curiosity rover is currently exploring this region of Mt. Sharp. In-situ analyses by the rover show changes in morphology and chemistry between the sulfate-bearing layers below and above the marker band and the marker band itself [3,4].

The MSL instrument payload includes the Mast Camera (Mastcam), which collects multispectral images to provide context for other instruments and broad mineralogic interpretations. In addition to mafic Fe-bearing minerals, Mastcam is sensitive to oxides and some hydrated minerals, important indicators of alteration [5]. In our previous work, we compiled a database of Mastcam spectra through Curiosity's exploration of Vera Rubin ridge (sols 0-2302), from which 9 spectral classes of rocks were identified (Fig. 1D). Each class has diagnostic spectral features that reflect a common mineralogic interpretation [6]. More recently, as Curiosity traversed through the clay-rich region, Glen Torridon (GT), there was some variation in the rock spectral classes potentially due to nontronite and other phyllosilicates, but not enough to warrant new spectral classes [7] (Fig. 1B). We hypothesize that new classes will appear in accordance with sulfate-bearing strata and the marker band, specifically appearing as a 'downturn' in the last two wavelength filters that is inherent, but not unique, to polyhydrated Mg-sulfates.

Here, we expand upon our analysis of Mastcam multispectral observations through Curiosity's second encounter with the marker band (up to sol 3672), comparing the spectral diversity within the sulfate-bearing unit and the marker band to the spectral classes encountered previously in the traverse. These analyses will provide a basis for comparison and aid in selecting targets for in-situ investigations as Curiosity continues its ascent of Mt. Sharp.

Methods: Mastcam is a multispectral, stereoscopic imaging instrument that can acquire visible to near infrared (VNIR) spectra in 12 unique wavelengths from ~400-1020 nm [8,9]. Raw sensor values are radiometrically and photometrically calibrated, using a reduction pipeline that includes near-simultaneous observations of a calibration target. Photometrically-calibrated I/F values are converted to reflectance factor (R*) by dividing by the cosine of the solar incidence angle. We applied a decorrelation stretch to all calibrated Mastcam images to highlight the color and spectral variability, which we used to identify regions of interest (ROIs) that are representative of the morphologic and color diversity within each scene. We extracted spectra by averaging pixels within each ROI and compiled a database with extensive metadata (including feature type, viewing geometry, sol, local true solar time, tau, elevation, LS, etc.). In order to interpret mineralogic trends across the full dataset, we used the Multispectral Data Explorer (MultiDEx) to efficiently analyze spectral parameter plots [10].

Results: We define three new spectral classes of rocks using data from (1) the Carolyn Shoemaker, Mirador, and Stimson formations; (2) an excursion above the marker band; and (3) the marker band itself (Fig. 1C,D). The "Red VIS Slope w/ Small 1013/937 nm" class (j in Fig. 1D) comprises the marker band blocks with high Fe, Mn, and Zn and some light-toned materials from above the marker band with high Cl and/or detections of Mg- and Ca- sulfates [3,4]. The "Long, Negative NIR Slope" class (k in Fig. 1D) is generally associated with dark, grey diagenetic features and Fe/Mg smectites [11,12] and refines the Neutral/Dusty class of Rice et al. [6] by separating spectra with subtle 867 nm band depths and 1012/751. The "Flat Profile w/ Small 1013/937 nm" class (l in Fig. 1D) is associated with basaltic DRT targets from Greenheugh Pediment [4]. Overall, the Mastcam spectral variability of sulfate-bearing strata and the marker band rocks is greater than was seen in GT (Fig. 1B,C), potentially due to the spectral masking effects of clay minerals in GT [13].

Discussion: The Caniama rock target is the first detection of crystalline Mg-sulfate by CheMin [14]. However, Mastcam spectra from Caniama are most consistent with the "Peak at 751nm w/ Small 1012/751nm" and "Long, Negative NIR Slope" classes (c and k in Fig. 1D); Caniama spectra do not exhibit the 1012 nm 'downturn' associated with hydration. Canaima's stronger absorptions around 867 nm may be attributable to hematite and/or goethite, as suggested by

CheMin data [14]. ChemCam and APXS have also detected small concentrations of Mg-sulfate in Mirador targets (e.g. [3,4]). However, laboratory spectroscopy investigations have shown that these concentrations of Mg-sulfate would not be sufficient to be detectable in Mastcam spectra [13, 15, 16]. Thus, these studies support that the downturns in spectra up to sol 3672 in the “Red VIS Slope w/ Small 1013/937 nm” and “Flat Profile w/ Small 1013/937 nm” classes (Fig. 1D) are not attributable to Mg-sulfate. Rather, orbital detections of high-Ca pyroxene in the marker band [2] suggest that Mastcam is capturing the left shoulder of a broad Fe2+ absorption longwards of~1.0 µm in spectra in the “Red VIS Slope w/ Small 1013/937 nm” class. CheMin detections of magnetite in Greenheugh Pediment targets [17] support the dark, flat spectrum characteristic of the “Flat Profile w/ Small 1013/937 nm” class (l in Fig.1D). **Acknowledgments:** Funding was provided by the Mars Science Laboratory Participating Scientist Program. We thank the students at WWU who have contributed to the Mastcam Multispectral database.

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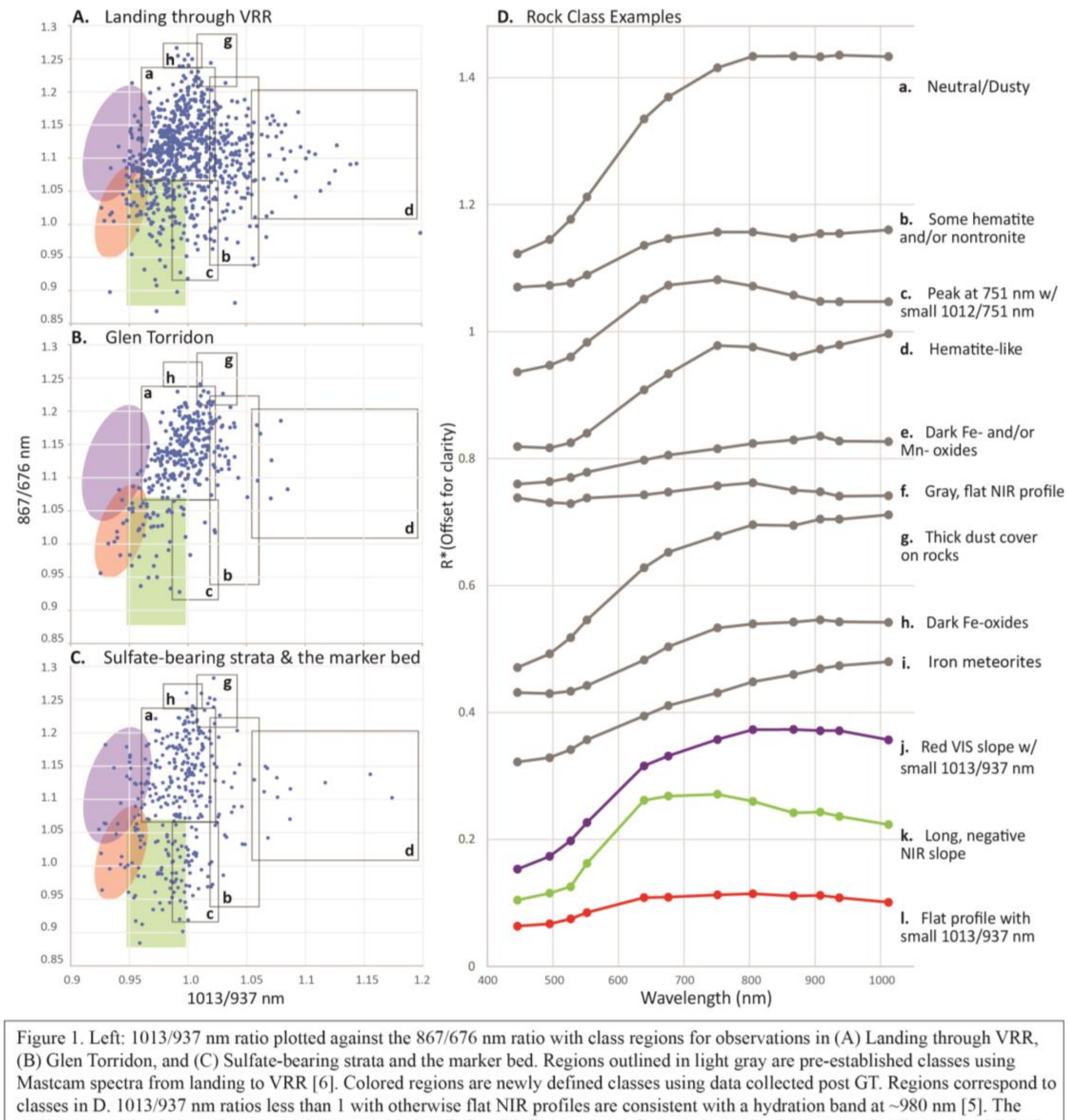

Figure 1. Left: 1013/937 nm ratio plotted against the 867/676 nm ratio with class regions for observations in (A) Landing through VRR, (B) Glen Torridon, and (C) Sulfate-bearing strata and the marker bed. Regions outlined in light gray are pre-established classes using Mastcam spectra from landing to VRR [6]. Colored regions are newly defined classes using data collected post GT. Regions correspond to classes in D. 1013/937 nm ratios less than 1 with otherwise flat NIR profiles are consistent with a hydration band at ~980 nm [5]. The 867/676 nm ratio characterizes spectral shape and helps distinguish flatter spectra from peaks or shoulders. Note that the pre-established classes “Dark Fe- and/or Mn- oxides”, “Gray, flat NIR profile”, and “Iron meteorites” are not highlighted by these spectral parameters. Right: (D) Example spectra of pre-established (grey) and newly defined classes (purple, green, red).